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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 95.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
July 9, 1914.

INSECT DAMAGE TO THE CONES AND SEEDS OF PACIFIC COAST CONIFERS.[1]

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INTRODUCTION.

Recent damage by insects to the cones and seeds of conifers has been brought to notice by the collectors of forest seeds. Compared with other commercial seeds the market price of forest seeds is high, owing to the limited demand, the special knowledge required for their collection, and the irregular production of conifer crops. A heavy percentage of damage materially decreases the profits of seed collection and may result in time and money fruitlessly spent. Seed that is badly infested or damaged by insects can not be sold to reliable dealers when its character is recognized.

It has been found that insects sometimes destroy practically all of the seed crop of a tree species in one locality in a season. In this respect insects have a certain relation to the future supply of timber, as the natural reproduction of forests is assured only by the production of a prolific supply of uninjured seed. (Pl. I, fig. *a*.) The artificial reforestation of denuded areas must also depend upon the collection of sound forest seed. An example of how insects may interfere with reforestation by a desired species has been furnished by the white fir on western national forests. Much of the seed of this species collected recently has been worthless for planting, a great percentage of this loss being due to insect damage in the cones and seeds.

Some information regarding insects that affect forest seeds and reproduction has been given in previous publications of the Bureau

[1] The names of the insects are not mentioned in this preliminary contribution because many of them are not yet named or described. When this has been done it is intended that a special bulletin on the subject shall be prepared by the same author.—A. D. HOPKINS, *in Charge of Forest Insect Investigations.*

NOTE.—Information regarding insects that seriously affect forest seeds, especially in the coniferous forests of the Pacific coast. A practical paper, of interest to seed collectors, dealers in forest seeds, and planters of forest areas; of particular application to Pacific coast regions.

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of Entomology.[1] This bulletin gives further facts regarding the character and extent of damage to the seed of coniferous forests of the Pacific slope. It also furnishes preliminary information on the more important groups of insects causing this damage, and their habits, that it may be available to seed collectors during the present spring and summer.

CHARACTER AND CAUSE OF DAMAGE.

Damage to the seed of conifers is caused by various species of insects which feed upon the buds, flowers, immature cones and seed, and mature seed. Great damage is accomplished while the cones are immature and before the seed ripens. Cones which are infested, or "wormy," are often found when the areas for seed collection are being located. Wormy cones and seeds are caused by the adults and grubs of small beetles, the "worms" or caterpillars of moths, the maggots of gnats, and the larvæ of tiny wasps known as seed chalcidids. In his work the seed collector usually encounters these immature stages of insects which depend upon the cone scales and seeds as their principal source of food supply. With the exception of the cone beetles the adult insect is seldom found in the immature cone. The insects may be found in almost any part of the cone or seed, the feeding habits varying much with the different species. In many cases the presence of these insects in the cone is evident and may be recognized by the peculiar type or class of injury. Where this is the case the damage may be approximately estimated during the summer.

With the more important seed-infesting insects the damage will be recognized in one or more of the following classes:

BLIGHTED CONES.[2]

The cones are sometimes killed when small and immature. As a result they wither and dry, and none of the seeds fill. Cones so affected are often described as blighted. Most of the injury of this character occurs in the cones of pine and is caused by the cone beetles. The attack is usually on the second-year cones, although the small first-year cones are sometimes killed. Some of the cone worms, also, bore into the cones in such a manner as to kill them and cause the same blighted condition. Sugar-pine cones attacked by the beetle nearly always fall to the ground during July and August. The cones of other species usually adhere to the tree for a winter or two. Damage of this type is easily recognized and can be estimated after the middle of July.

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[1] Hopkins, A. D., Catalogue of exhibits of insect enemies of forests and forest products at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. U. S. Dept. Agr., Div. Ent., Bul. 48, p. 13–14, 33, 1904.

Hopkins, A. D., Insect enemies of forest reproduction. U. S. Dept. Agr. Yearbook, 1905, p. 250–251, 1906. (Yearbook Separate 381.)

Rohwer, S. A., VI, Chalcidids injurious to forest-tree seeds. U. S. Dept. Agr., Bureau of Entomology, Tech. Ser. 20, Pt. VI, p. 157–163, Feb. 10, 1913.

[2] Pl. I, figs. *c1*, *d*; Pl. II, figs. *a*, *b*.

WORMY AND ABORTED CONES.[1]

In some forms of injury the cone is not killed, but may show masses of resin on the surface, castings caused by the feeding of larvæ, or little burrows through the scales, seed, and pith which contain small larvæ. In rare cases the cone may be aborted or deformed, forming a peculiar growth or shape. The cone, however, continues to grow and matures at the close of the season very much like a normal one. The seeds which are not mined or eaten by the insects fill and mature. Damage of this character may be found in practically all species of conifers. Much of it is caused by the caterpillars of different species of moths, some of which show nothing on the surface of the cone to indicate their work in the interior. The amount of damage to the seed of western yellow pine and Jeffrey pine throughout northern California and southern Oregon in 1912 was estimated by the writer to vary from 50 to 90 per cent of the crop.

WORMY SEED.[2]

This class of injury is found only in the seeds. The cone is not affected and shows no indication of the insect. Practically all of the reported damage of this type is caused by the larvæ of tiny wasps called seed chalcidids. A certain percentage of the seeds will be infested by a small, white, headless larva. The infested seeds are of normal size and appearance. The larvæ feed entirely within the inner lining of the seed. Damage of this type can be found only by cutting the seed open. Seeds which have been attacked are hollow and usually contain the small headless larvæ of the chalcidid. After the seed has been stored over winter some of the adults emerge, boring small clean-cut holes through the outer shell of the seed. This is the first external indication of these insects. Quite often seed infested by the seed chalcidid is collected and sold before the infestation is detected. Injury of this type is very common in certain species of fir, in which the damage has sometimes been found to run as high as 75 to 90 per cent of the cleaned seed. Species of seed chalcidids have also been found in the seed of western yellow pine and Engelmann spruce.

MAGGOTY CONES.

Many cones are injured by the maggots of flies and midges, some of which cause no appreciable damage to the seed. Small whitish or pink-colored maggots are found in the cones of nearly all conifers. They are the larvæ of tiny gnats, or midges. The pinkish maggots cause little masses of resin among the scales but do not seriously affect the seeds. The whitish maggots in fir cones cause considerable damage to both cone and seeds. (See Pl. III, figs. *a*, *c*.) They are often present in vast numbers and leave the cones when these are

[1] Pl. I, fig. *b*

[2] Pl. III, figs. *b*, *d*.

spread to dry. They are among the most common insects noted in the work of seed collecting.

IMPORTANT GROUPS OF SEED-INFESTING INSECTS.

There are four important groups of insects which cause practically all of the serious damage under the four classes described.

CONE BEETLES.

Cone beetles are small, dark, cylindrical beetles which attack the cones of pines. The cones are killed by the attack of the adult, which bores a small tunnel into the axis to deposit its eggs. (Pl. II, fig. *b 1*.) The larvæ (Pl. I, fig. *d*) feed on the seeds and scales of the withering cone and develop to the beetle stage within the dead cone, where the beetles usually remain over winter. The attacks of several species of these beetles are very common in western yellow pine and sugar pine. The damage to crops of sugar pine is considerable, as these beetles have been noted in some seasons to kill from 25 to 75 per cent of the cones over large areas.

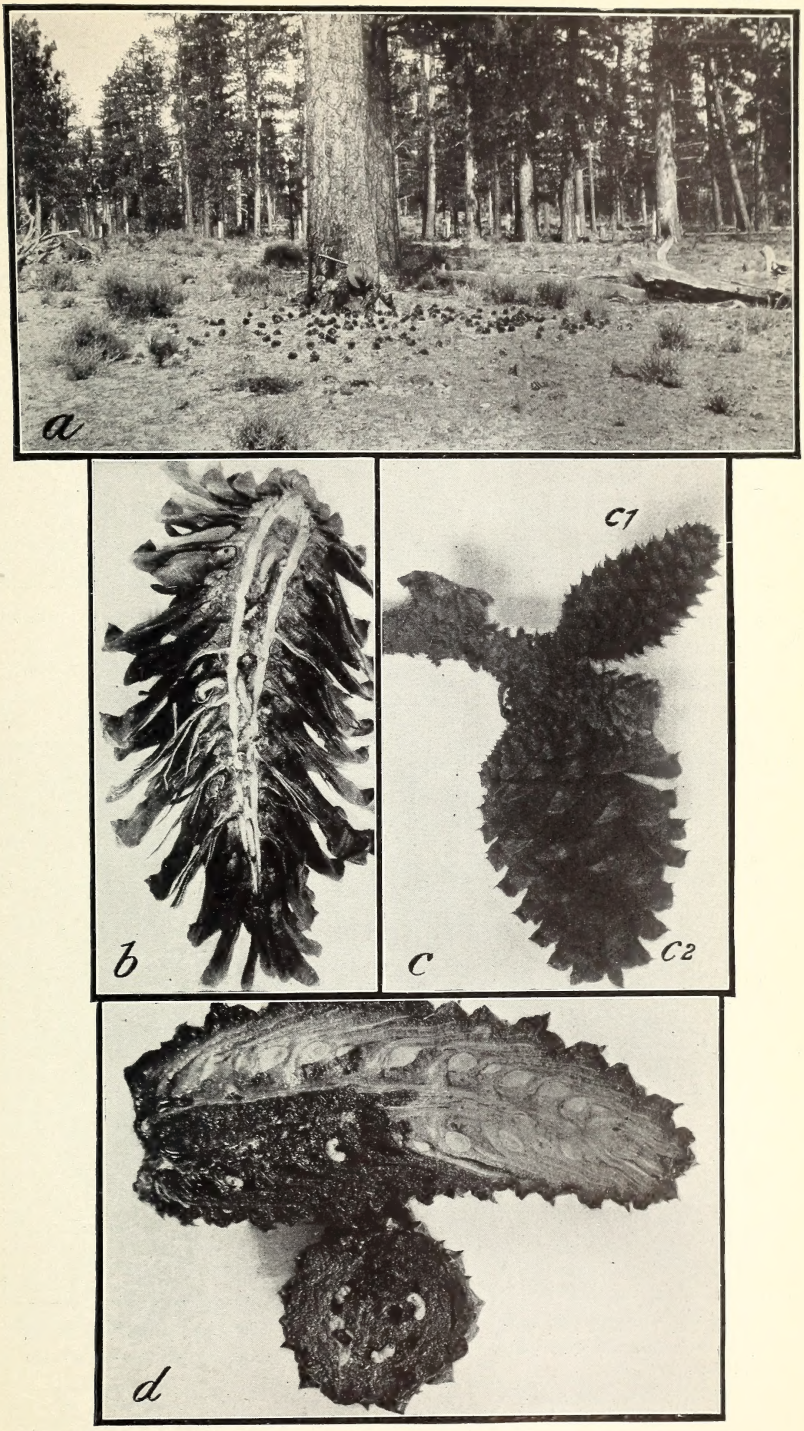
CONE WORMS.

Cone worms are most frequently met with in the cones in the caterpillar stage. They represent several species of moths which infest the cones of pines, firs, hemlocks, and spruces, and even the seed of incense cedar has been found to be attacked by the tiny larvæ. The moths are small and in most species dull colored and inconspicuous. The small white larvæ of one species are very common in the cones of western yellow pine and Jeffrey pine. They feed upon the seeds and scales without killing the cone and overwinter as larvæ and pupæ in galleries in the pith of the cone axis. (Pl. I, fig. *b*.) Another species is a very common enemy of Douglas fir seed on the Pacific slope. The larvæ mine a gallery through the scales, leaving an opening at the surface through which resin and larval castings exude. The pupæ overwinter near the axis in resinous cocoons among the scales. Nearly all species feed without killing the cone, but a large caterpillar feeding on western yellow pine sometimes kills the immature cone, the damage resembling that of the cone beetle.

SEED CHALCIDIDS.

The adults of seed chalcidids are tiny wasps (Pl. III, fig. *d*). The larvæ (Pl. III, figs. *b*, *d*) live within the seeds, apparently developing as the seeds grow, so that the infested seeds reach normal size and

EXPLANATION OF PLATE I.—*a*, Photograph near Bray, Cal., showing cones of western yellow pine on ground, but poor reproduction; *b*, mature western yellow pine cone, showing pith occupied by the cone worm and seeds destroyed by it; *c1*, blighted western yellow pine cone caused by the cone beetle; *c2*, normal cone; *d*, young living western yellow pine cone, greatly enlarged, to show character of damage by the cone beetle and its larvæ. (Original.)



INSECT DAMAGE TO REPRODUCTION OF WESTERN YELLOW PINE.

[For explanation of plate see note at foot of page 4.]

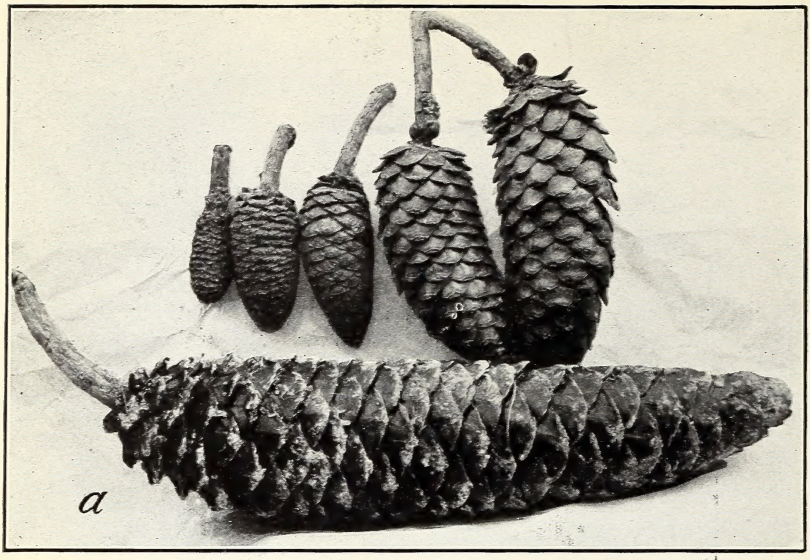


FIG. A.—SUGAR-PINE CONES ATTACKED BY THE CONE BEETLE AT DIFFERENT STAGES OF GROWTH OF THE CONE. (ORIGINAL.)

[The longer cone, which is about 14 inches long, resisted attack, while the others were killed.]

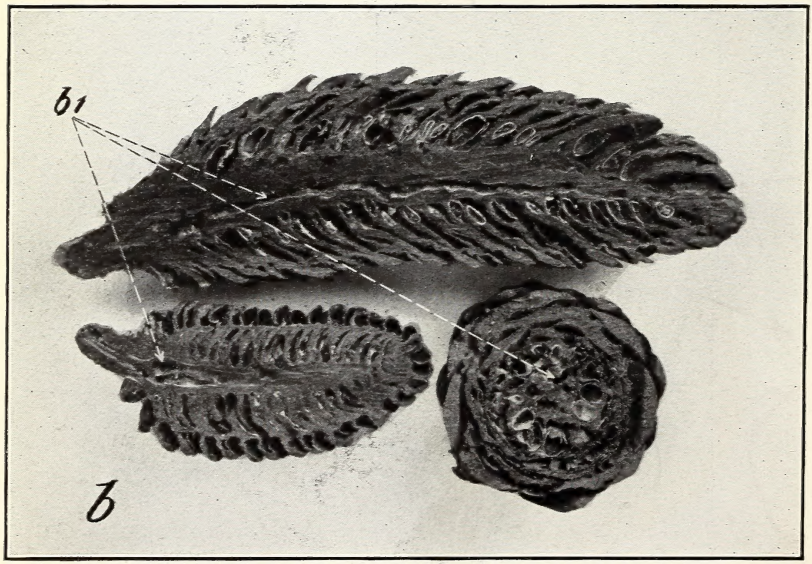
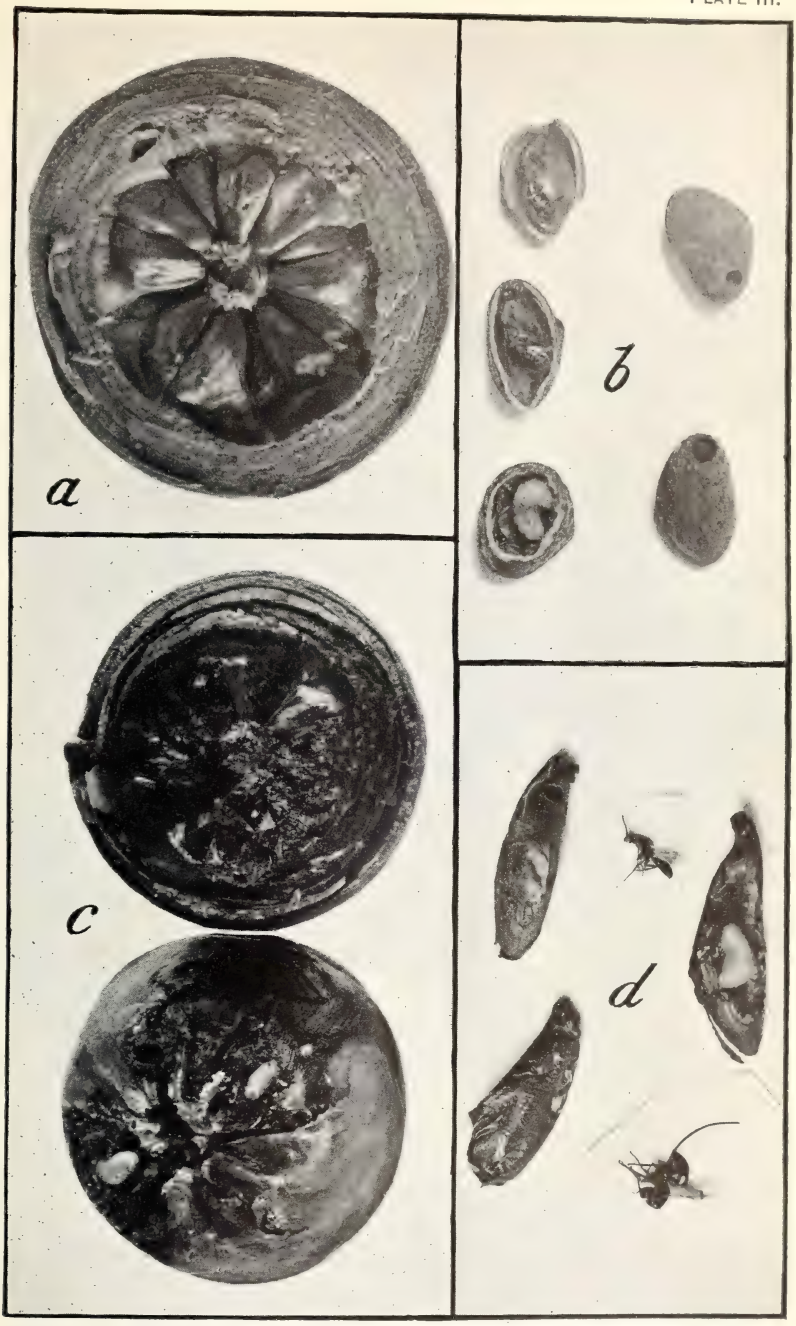


FIG. B.—LONGITUDINAL AND TRANSVERSE SECTIONS OF SUGAR-PINE CONES, NATURAL SIZE, SHOWING PRIMARY EGG GALLERIES, B1, MADE BY THE CONE BEETLE. (ORIGINAL.)

WORK OF THE CONE BEETLE IN SUGAR PINE.



WORK OF A CHALCIDID IN SEEDS OF PACIFIC COAST CONIFERS.

a, Cross section of sound, mature white fir cone with unaffected seed; *b*, yellow pine seed, enlarged, infested by larvæ and newly transformed adults of a seed chalcidid; two unopened seeds show exit holes made by these insects; *c*, cross sections of two maggoty white fir cones; *d*, male and female adults of seed chalcidid, larva in opened seed of red fir (*Abies magnifica*), and exit holes in two other seeds of same. (Original.)

form. There are several species, one of which is very destructive to the seed of Douglas fir, white fir, and red fir.

FIR-CONE MAGGOTS.

Fir-cone maggots are the larvæ of small gnats which have been found in the cones of white fir, red fir, and alpine fir. They mine through the scales and seeds, causing great damage. The larvæ do not winter in the cones but burrow into the ground as soon as the cones fall. They form small puparia within an inch or so of the surface, and there they overwinter.

ADAPTATION OF THE INSECTS TO THE INTERMITTENT CONE-PRODUCING HABITS OF THE HOST TREES.

There is a general life cycle for most of the cone-infesting insects corresponding to the period required by the host tree to develop the seed crop. The adult insect, whether beetle, moth, fly, or seed chalcidid, deposits the eggs in the spring or early summer while the cones are small and undeveloped. With some species the attack is such that the cone is killed; with others the attack and feeding of the larvæ do not interfere with the growth of the cone, which matures at the normal time, although much of the seed may be destroyed. The feeding of the larvæ ceases, however, when the cone matures, usually during September. The insects then undergo a long dormant period either as larvæ, pupæ, or new adults. This dormant period continues until there is another crop of cones in a proper condition for attack; that is, the soft, immature cones which are found in the spring or early summer. Some insects pass this dormant period in the pith of the cones or in resinous masses among the scales. Other species leave the cones and form the pupæ in the ground or in débris on the surface.

The intermittent character of the seed production of conifers is a well-established fact.[1] A few cones are produced every year, but a good crop occurs at intervals of from two to five years. The years of total failure are known as "off years." It is evident that if the entire brood of any of these species of cone-infesting insects emerges annually, it will sooner or later encounter an off year of the host tree. This would mean the complete failure of the food supply for one generation and would result in the almost complete extinction of the species within the forest area affected by the crop failure. As a matter of fact, observations show that this seldom happens. All the individuals of a brood of overwintered insects do not emerge the following spring. Many of them do emerge after the first winter, but a large percentage of the brood, in some species 50 per cent or more,

[1] U. S. Dept. Agr., Forest Service, Bul. 98, p. 13, Nov. 18, 1911.

continues for another year in the same condition in which the first winter was passed. Usually this retarded part of the brood emerges at the end of the second winter or spring.[1] This is an adaptation which to a certain extent accounts for the continued infestation of certain species of insects in the seed of forest trees. In the case of a species of gnat which infests the cones of white fir it was found that the entire brood of insects which destroyed the 1911 crop of seed on an area in northern California did not emerge at all in the spring of 1912, but remained in the pupal state through the summer of 1912 and the following winter. The adult flies finally emerged in the spring of 1913. Under this adaptation it would appear that only a continued failure of the crop through a series of years would result in the reduction of the numbers of the infesting species on a forest area. Undoubtedly other agencies are responsible for the uninfested condition of the seeds of certain trees during some seasons.

INDICATIONS OF INSECT DAMAGE.

Attack of the cone beetle in the seed crop is indicated by a small entrance hole at the base of the cone, with castings or small pitch tubes, during the early summer; later, by the brown, withered appearance of the cone.

The attack of the cone moth may sometimes be recognized by little masses of pitch and larval castings on the surface of the cone and sometimes by withered cones, but it is best to look for the caterpillar among the scales and in the seed and pith. It is always best to cut the cone open, sectioning it several different ways, in making the examination.

The attack of the fir-cone maggot can also be found by cutting or breaking the cone open. The larval mines will be found in the scales and seeds, in which will usually be found the small, white, active larvæ.

The seed chalcidids show no external evidence, and the seeds must be sectioned or otherwise opened to find the larvæ of these insects. Unless test is made the amount of damage can not be determined, and seed that is badly infested may be taken as sound.

METHODS OF PREVENTING LOSSES.

There are areas of light infestation by these insects in certain species of trees, and there are areas where the damage is very heavy. The amount of infestation in the seed may also vary with succeeding seasons. A careful examination of the cones before the seed matures, during July and August, will usually reveal immature stages of the seed-infesting insects. If cones of the past season are examined during the winter and spring, they will indicate whether or not the

[1] This retarded emergence has not been observed in the case of the cone beetles, but it has been observed in the more important cone worms, fir-cone maggots, and seed chalcidids.

area is infested by these insects. In the collection and cleaning of forest seeds there is opportunity for use of the information which is now being gathered on this subject. An intelligent selection of the seed-collecting areas will prevent much of the loss due to gathering seed which is afterwards found to be infested or worthless.

A count of the number of infested cones and of damaged seeds will give a clue to the percentage of damage in the crop. Whether or not the damage is sufficient to make collection of the seed unprofitable on the area will have to be determined by the collector.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914